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TITLE: REPETITIVE MEGAMP PER MICROSECOND dI/dt PULSERS FOR DRIVING SUB-OHM TRANSMISSION LINE NEUTRINO PARTICLE DETECTORS

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REPETITIVE MEGAMP PER MICROSECOND di/dt PULSERS
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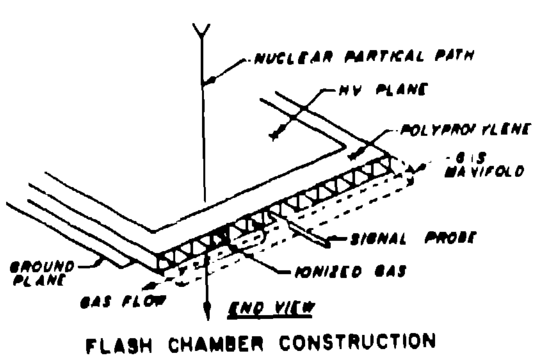
Summary

With the advent of low-cost honeycomb extrusions of polypropylene sheets, transmission line flash chambers have become highly attractive candidates for large particle detector arrays. This has brought about the need for repetitive pulse systems that must provide exceptionally high peak currents, low levels of spurious radiation, high reliability, and shot life in excess of 10^7. Each module of 10 flash chambers requires a peak current of 20 kA with a current di/dt greater than 1 MA/μs. The pulser output must develop ≈7 kV across a load of 0.5 Ω with a pulse width of 500 ns. The complete system will require 40 pulsers run in parallel for a combined current output of 1.4 MA peak with a system di/dt of 40 MA/μs. The repetition rate will be up to 2 Hz. This paper describes the development of such a system, its unique voltage and current diagnostics, and the impact of the physical limitations of present component technology on lifetime, reliability, maintainability, and pulse fidelity.

Introduction

In an article published in Nuclear Instruments and Methods, Volume 158, page 289 (1979), a system was discussed which allowed rapid data collection from particle detectors known as "flash chambers." A flash chamber consists of a noble gas mixture confined between two conducting plates in a dielectric container. The conducting plates are pulsed to a high-voltage level in coincidence with the passing of a charged particle and a plasma is then formed in the dielectric container. At this point, the data may be extracted optically or, in some cases, electrically. Until recently, data collection from flash chambers was a slow and tedious process because a photographic method was employed. Complexity of construction and high cost have also curtailed the use of these novel detectors, but with the advent now of low-cost honeycomb extrusions of polypropylene sheets, flash chambers (Fig. 1) have become very attractive components for large particle detector arrays. The flash chamber readout system developed at LASL can output data at a rate ~2.5 x 10^4 bits per interrogation. The period of one interrogation is less than 0.01 s as compared to the previous optical system outputs of several hundred bits requiring seconds or minutes to accumulate. It is clear that this new readout method will be of considerable utility.

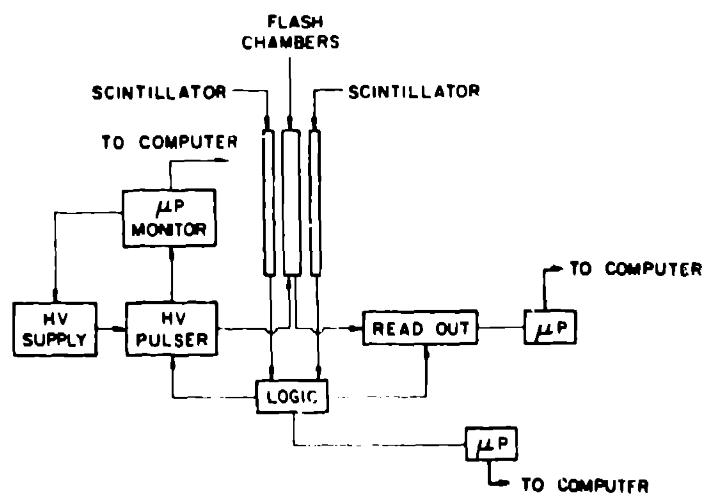


FLASH CHAMBER CONSTRUCTION

Fig. 1.

At that point in the system development, however, it was dependent on substantial technology base developments in the high-voltage pulse power driver.

Figure 2 shows a simplified, overall block diagram of the instrumentation system. In this system, the flash chamber readout, high-voltage pulser, and the voltage monitors are the major areas of development. The high-voltage pulser is the focal point of this report. This pulser can be divided into four separate areas: the load, energy storage, load-to-pulser interface, and switch. These areas will be discussed in this order.



EXPERIMENTAL CONFIGURATION

Fig. 2.

The Load: The flash chambers for this system are 3-1/2 m by 3-1/2 m with a thickness of 5 mm, and are clad on both sides with 0.05 mm of aluminum foil, forming a parallel plate capacitor with a capacity of 20 nF. Since these chambers have dimensions comparable to the pulse rise and fall times, they cannot be treated as conventional transmission lines. Instead, they are being analyzed more as distributed capacitive and inductive elements than a true transmission line. In order to have a point of reference, the impedance of a chamber was measured and found to be ≈5 Ω, and the transit time was measured to be 10 ns. The above parameters constitute the predominant characteristics of the flash chamber as an electrical load. In the planned experiment, there will be 400 flash chambers and each pulser will have to drive a module consisting of 10 chambers. This means a load of 0.5 Ω and 200 nF for each pulser.

Energy Storage: For high resolution and peak efficiency, the flash chamber requires a rectangular high-voltage pulse with a duration dependent on the chamber's physical size (in our case, 500 ns and a source impedance of 5 Ω). A pulse-forming network (PFN), was used to meet these needs. In the first stages of PFN design, computer modeling was used to arrive at a prototype design. This prototype PFN was then tested under load conditions and adjusted to compensate for distributed parameters not included in the modeling program. Since high-peak currents and low inductance are required in conjunction with a lifetime of 10^7 shots (MTBF, 90% confidence level), capacitor selection was nontrivial. Figure 3 shows the data from which capacitors for the PFN were selected. Although the Axel capacitors seem the most likely candidate, budgetary restraints required a more cost-effective choice. Considering the lifetime cost and ESR data, the emphasis has been placed upon the development of a PFN utilizing mylar capacitor manufactured by Condensor Products.

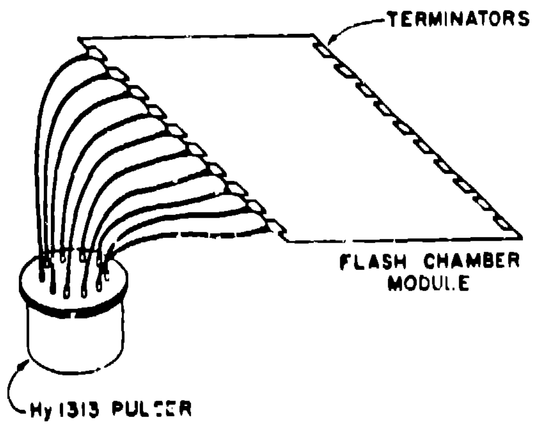
MANUFACTURE	TYPE	SHOT LIFE	ESR	COST (SINGLE UNIT)
AXEL	MP-5AW	10^{10}	.66 Ω	$72.00
CONDENSER	MSB-103			
PRODUCTS	-15 MX	10^7	2.32 Ω	$8.00
MURATA	DHS	10^4	.41 Ω	$6.00
SPRAUGE	720C	10^6	2.05 Ω	$6.00

ALL CAPACITOR WERE 10nF UNITS

CAPACITOR DATA

Fig. 3.

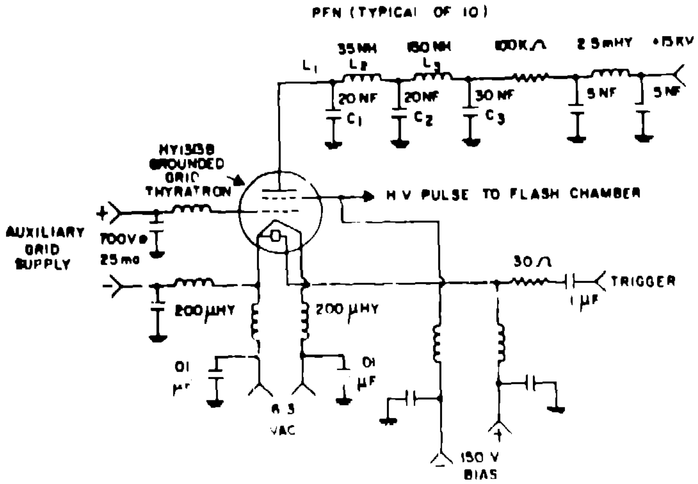
Load-to-Pulser Interface: In transmitting the power from the switch and PFN assembly to the chambers, the characteristics of both strip-line and coaxial transmission lines have been assessed. Coaxial lines have yielded the best results so far and seem to be the most cost-effective. Figure 4 illustrates the pulser-to-load interface geometry. The pulse is fed to the module via ten bundles of coaxial cable, each bundle consisting of six 31-Ω cables in parallel. Each module is fed evenly along one edge and is terminated along the edge opposite the feed.



PHYSICAL LAYOUT OF PULSER AND LOAD

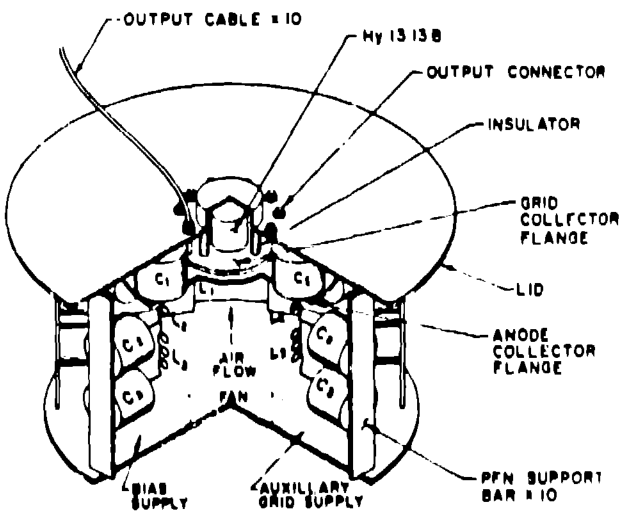
Fig. 4.

The Switch: After an extensive market study and vendor interactions, an EG&G thyratron was chosen for initial prototyping. The choice of a thyratron over a spark gap was based on the low spurious noise requirement and a $>10^7$ shot life. EG&G has developed a new grounded grid thyratron, the HY-1313B, for our specific application. Figure 5 shows the HY-1313B pulser schematic and Fig. 6 shows the physical layout. The thyratron is mounted upside down in order to reduce the output lead length as much as possible. Ten PFNs surround the HY-1313B in a folded wagon-wheel arrangement. This geometry allows very close placement of the first mesh of the PFN while conserving space by folding meshes two and three. To date we have tested the Hy-1313B to a peak current of 20×10^3 A at the 10% to 90% points into a 0.5-Ω, 200-nF load and were able to obtain a current rise time of 16 ns (this means a di/dt of 1.25 MA/μs) (Fig. 7) and a maximum peak current of 32×10^3 A with a voltage rise time of 50 ns (Fig. 8).



HIGH VOLTAGE PULSER

Fig. 5.



Hy1313B PULSER PHYSICAL LAYOUT

Fig. 6.

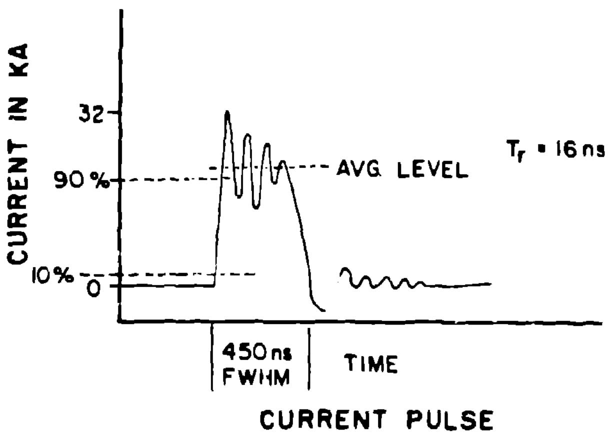


Fig. 7.

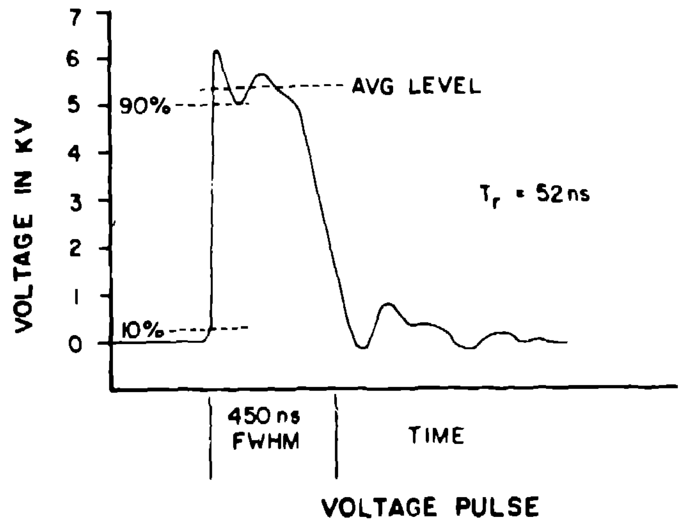


Fig. 8.

Conclusion

Considering shot life, cost, and ESR, the Condensor Products capacitors are being used for further testing of the PFN. The HY-1313B, at the present stage of testing, has successfully driven 100% of the load and looks acceptable at this time. It appears that several changes could improve system performance--a further compression of component density in the vicinity of the HY-1313B, and use of the lower ESR Axel capacitors. Both could have a significant effect on current rise time. In addition, use of a ferrite toroid surrounding the thyratron to improve switching time might also be beneficial.